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Using Orchardgrass and Endophyte-Free Fescue Versus Endophyte-Infected Fescue Overseeded on Bermudagrass for Cow Herds: II. Four-Year Summary of Cow-Calf Performance

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ABSTRACT

A 4-yr trial was initiated in January 2000 to evaluate cow-calf performance on mixed-species pasture systems consisting of (i) endophyte-infected tall fescue (E+; *Festuca arundinacea* Schreb.) diluted by approximately 50% with common bermudagrass [*Cynodon dactylon* (L.) Pers.] and other forages; (ii) endophyte-free tall fescue (E−) overseeded into dormant common bermudagrass; and (iii) orchardgrass (OG; *Dactylis glomerata* L.) established under the same conditions as E−. The E− and OG pastures were grazed with either twice weekly (2W) or twice monthly (2M) rotation schedules, while pastures with E+ were grazed with 2M only. Actual weaning weights tended to be greater ($P = 0.096$), and age-adjusted 205-d weaning weights and average daily gain from birth to weaning were greater ($P \leq 0.035$) for calves raised on low-toxicity (E− or OG) pastures compared to those raised on E+. Over 4 yr, calves raised on low-toxicity pastures exhibited 22- and 24-kg advantages in actual and 205-d adjusted weaning weights, respectively, compared to those raised on E+. Cows grazing OG and E− pastures exhibited greater ($P \leq 0.021$) body weights and body condition scores (BCS) at calving than cows grazing E+ pastures. Furthermore, reductions in body weight and BCS between calving and weaning tended to be greater ($P \leq 0.088$) for cows grazing E+ pastures. Calf performance was improved consistently by these low-toxicity pasture systems, but management requirements may limit adaptation by producers.

The fungus *Neotyphodium coenophialum* (Morgan-Jones and Gams) Glenn, Bacon, and Hamlin comb. nov. (Glenn et al., 1996) that exists in symbiotic association with tall fescue produces toxins that affect livestock performance negatively. While debate continues concerning the chemical structure(s) of these toxins, as well as their possible modes of action (Hill, 2005), many of their effects on livestock occur consistently. Specifically, the adverse effects of these toxins on cows, calves, growing heifers, and stocker cattle include reduced intakes of dry matter (DM) (Goetsch et al., 1987a, 1987b; Forcherio et al., 1995; Humphry et al., 2002), poorer fiber digestion (Hannah et al., 1990; Humphry et al., 2002), elevated rectal temperatures (Goetsch et al., 1987a; McMurphy et al., 1990; Parish et al., 2003), depressed concentrations of serum prolactin (Fribourg et al., 1991; Parish et al., 2003; Watson et al., 2004; Nihsen et al., 2004), rough hair coat (Fribourg et al., 1991; Peters et al., 1992; Nihsen et al., 2004), increased respiration rates (Peters et al., 1992; Nihsen et al., 2004), depressed weight gains (Read and Camp, 1986; McMurphy et al., 1990; Fribourg et al., 1991; Peters et al., 1992; Parish et al., 2003; Watson et al., 2004; Nihsen et al., 2004), and reduced milk production (Holloway and Butts, 1984; Peters et al., 1992). Taken in total, these problems cost livestock producers in the USA an estimated $609 million annually (Hoveland, 1993).

Recently, associations of improved tall fescue varieties with novel endophytes that produce no or minimal measurable toxins (Bouton et al., 2002; Nihsen et al., 2004) have become available commercially, and these associations appear to alleviate many of the problems associated with fescue toxicosis (Parish et al., 2003; Watson et al., 2004; Nihsen et al., 2004). However, renovation of many E+ pastures throughout the southern Ozarks is complicated by the rugged nature of the terrain, marginal productivity of the soils, unsuitability of many pastures for tillage, loss of the pasture from productive use during renovation, and the costs of establishment. Historically, dilution of E+ pastures with other nontoxic grasses or legumes has been suggested as a partial remedy for fescue toxicosis in cow-calf enterprises (Ball et al., 2002), and both cow (Holloway and Butts, 1984) and stocker cattle performance (McMurphy et al., 1990) have been improved by diluting E+ pastures with legumes. Throughout the southern Ozarks, a natural measure of dilution is created via the adaptation and competitiveness of bermudagrass within tall fescue pastures. The competitiveness of bermudagrass within tall fescue–bermudagrass mixtures

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Abbreviations: BCS, body condition score; DM, dry matter; E+, endophyte-infected tall fescue; E−, endophyte-free tall fescue; OG, orchardgrass; 2M, rotation to new paddocks twice monthly; 2W, rotation to new paddocks twice weekly.

can be affected by the amount and timing of N fertilization, as well as the timing, frequency, and height of mowing or grazing (Wilkinson et al., 1968; Hoveland et al., 1978; Fribourg and Overton, 1979; Pitman, 1999). Generally, the frequently observed habit of overgrazing by cow-calf producers throughout the southern Ozarks tends to enhance the competitiveness of bermudagrass by reducing shading by upright-growing cool-season grasses, thereby allowing more light to penetrate to the soil surface. Bermudagrass is a C_4 forage that has a higher photosynthetic rate and efficiency at high radiation than C_3 forages (Nelson, 1995), but it is less tolerant of shading in mixed pastures than upright C_3 forages (Hoveland et al., 1997).

In a companion report (Coblentz et al., 2006), we described the forage mass, nutritive value, species composition, and toxicity of common bermudagrass pastures overseeded with E− or OG for spring-calving cows measured over a 4-yr period. These forage systems were compared with typical mixed-species pastures containing approximately 50% E+, with the remaining 50% consisting of common bermudagrass and various other forages found commonly throughout the southern Ozarks. The objective of this study was to evaluate livestock performance by spring-calving cows and calves grazing pasture systems described previously (Coblentz et al., 2006).

MATERIALS AND METHODS

Management of Cattle and Pastures

Pasture Management and Location

This study was conducted at the Batesville Livestock and Forestry Branch Station (35°50′ N, 91°48′ W), located near Batesville, AR. The experimental site covered 52 total ha, and was divided into thirteen 4-ha pastures. The OG and E− experimental pastures were grazed with rotational grazing schemes that included rotations to fresh paddocks either 2W or 2M. Pastures grazed with the 2W rotation frequency were subdivided into eight 0.5-ha paddocks that were grazed for 3 to 4 d during each rotation, and then rested for the balance of the month (≈26–28 d). Cows assigned to 2M pastures were maintained on a specific 2.0-ha paddock for ≈15 d before they were rotated to another paddock of the same size for the remainder of the month. The E+ pastures were grazed with the 2M rotation frequency only. All other specific details related to establishment, fertilization, grazing management schemes, forage mass, species composition, toxicity, and nutritive value of all experimental pastures are described in detail in a companion report (Coblentz et al., 2006).

Description and Allocation of Cows

All procedures for cattle management and care were approved by the University of Arkansas Animal Care and Use Committee. Sixty-five spring-calving cows (547 ± 69.3 kg) were stratified by weight, age, and breeding and assigned to one of the thirteen 4-ha pastures (five cows per pasture) on 11 Jan. 2000. Initially, one or two cows per pasture had a Hereford sire and Brahman × Angus dam; the balance of the cows was purebred Angus. Cows initially assigned to a specific pasture remained on their assigned pasture continuously throughout the trial to assess the cumulative effects of each grazing system on animal performance. Beginning on approximately 15 May of each year, one Gelbvieh bull was assigned to each pasture and remained on that specific pasture for a 60-d breeding season. Each year, bulls were rotated to pastures where they had not been assigned previously to prevent them from mating with the same group of cows during more than one breeding season over the 4-yr trial. Cows were checked for pregnancy by rectal palpation in January of each year, and any open cows were replaced at that time with pregnant primiparous heifers. Similarly, any cows without live calves at the end of the calving season (1 May) were replaced with a primiparous cow and her calf.

Cow and Calf Health

Cows were vaccinated against seven clostridial strains (Alpha 7, Boehringer Ingelheim Animal Health, Inc., St. Joseph, MO) approximately 2 wk before the onset of calving; they also were vaccinated against infectious bovine rhinotracheitis, bovine virus diarrhea, parainfluenza, bovine respiratory syncytial virus, *Haemophilus somnus*, and five strains of *Leptospira* (Elite 9-HS, Boehringer Ingelheim Animal Health, Inc.) approximately 2 wk before breeding was initiated. Cows were treated for internal parasites at the same time they were vaccinated for clostridial strains with moxidectin (Cydectin, Fort Dodge Animal Health, Fort Dodge, IA), and Permectin CDS (Boehringer Ingelheim Animal Health, Inc.) was used as needed to control external parasites.

Supplementation

No supplemental concentrates were offered to cows or calves at any time during the 4-yr trial. A commercial trace mineralized salt (900 to 950 g kg^{-1} NaCl, and not less than 300 mg kg^{-1} Mg, 100 mg kg^{-1} K, 100 mg kg^{-1} Co, 300 mg kg^{-1} Cu, 70 mg kg^{-1} I, 6500 mg kg^{-1} Fe, 1700 mg kg^{-1} Mn, and 2000 mg kg^{-1} Zn) was provided ad libitum throughout the year. During the spring, a commercial mineral package with a minimum of 135 g kg^{-1} Mg, 80 g kg^{-1} Ca, 20 g kg^{-1} P, 180 g kg^{-1} NaCl, along with trace minerals was provided to reduce the incidence of grass tetany.

Bermudagrass hay was offered in large round-bale feeders when forage became limiting or when cows preferentially grazed E− or OG forages too closely; specific details describing the decision triggers for initiating supplemental hay feeding, and methodology for offering supplemental hay are summarized in the companion report (Coblentz et al., 2006). The number of bales offered on each pasture was recorded, and total hay offered was estimated on the basis of an average bale weight (516 ± 6.1 kg). Periodically, grab samples were taken from the bermudagrass hays offered during the trial. Samples were dried at 50°C under forced air, ground through a Wiley mill (Arthur H. Thomas, Philadelphia, PA) equipped with a 1-mm screen, and then retained for laboratory analyses of nutritive value.

Cattle Measurements

Weights and Body Condition Scores

Cows and calves were weighed monthly except during the calving season; body condition of all cows was scored (BCS; scale: 1 = emaciated, 9 = obese; Davis, 1995) by the same trained evaluator on each weigh day. For cows, weights and BCS were reported at the beginning of the calving season, and differences were calculated for the following time intervals: (i) calving to breeding; (ii) breeding to weaning; and (iii) calving to weaning. For calves, actual weaning weight, age adjusted 205-d weaning weight, and total and average daily gain from birth to weaning were reported as weight-related response variables. All reported weights and weight changes were obtained or calculated without withholding forage or water. Age adjusted 205-d weaning weights were calculated for each calf by first determining the average daily gain between birth and weaning, then multiplying this daily rate of gain by 205 d, and then adding the animal's birth weight. Age-adjusted 205-d weaning weights were not adjusted for the age of the dam. Within each year, all calves were weaned on the same day; therefore, this age adjustment was made to normalize differences in birth date for individual calves, which were spread generally over a 2-mo period each spring.

Milk Production

Milk production was estimated in May and July of each year by a modification of the weigh-suckle-weigh procedure (Williams et al., 1979). Cows and calves were removed from their assigned pastures at approximately 0800 h; calves were then separated from their dams and held without feed or water until approximately 1600 h when they were allowed to nurse. After nursing, calves were again separated from their dams until approximately 0900 h the next morning when calves were weighed, allowed to nurse their dams, and weighed again approximately 10 min later. Weight gain following nursing was extrapolated to a 24-h basis and reported as estimated daily milk production. During 2000, milk production was estimated as described; however, in an effort to reduce variability associated with this measurement, milk production for each cow was estimated on two successive days from 2001 through 2003. In these cases, the mean of successive daily estimates was used as the estimated milk production for each cow. During the time period that milk production was estimated, cows were maintained on a 2.6-ha mixed-species pasture located immediately adjacent to the holding pens. Fresh water was available at all times.

Performance of Extra Grazing Cows

In an effort to control the flush of forage growth that occurs during the spring, extra "thin" fall-calving cows were assigned to each pasture to improve their body condition. This technique was used because all pastures were not suitable for measuring any extra forage produced as hay, and because this measurement can serve as an indirect indicator of the productivity of each forage system. Furthermore, numerous producers throughout Arkansas have experimented with variations of this technique in recent years; typically, "thin" cull cows are purchased from sale barns or from other sources before the flush of early-spring growth, allowed to graze lush pastures while forage growth and subsequent weight gains are rapid, and then sold as an extra source of revenue. The same principle and timing also can be applied to improve the body condition of fall-calving cows with suckling calves at the conclusion of the winter hay-feeding period.

For this study, extra cows were assigned to a specific 4-ha pasture and they remained there as long as forage availability permitted. Generally, extra grazing cows were removed when forage mass was reduced to approximately 4000 kg ha^{-1}, but recent rainfall, forage regrowth rate, and other factors also were considered with a management goal of minimizing summer hay feeding. Within each pasture, extra grazing cows were co-mingled and otherwise grazed within the same rotation schedule as the five permanently assigned cows. Extra cows were weighed when assigned, and then on removal from each pasture. Body condition score was assessed as described previously (Davis, 1995). Total grazing days per hectare, total weight gain, average daily gain, changes in body condition score, and total gain per hectare for these cows were reported as response variables.

Laboratory Analyses

Concentrations of neutral detergent fiber (730 ± 12.0 g kg^{-1}) and acid detergent fiber (383 ± 29.7 g kg^{-1}) in supplemental bermudagrass hays were determined by the batch procedures outlined by ANKOM Technology Corporation (Fairport, NY). The ANKOM methods used in this study have been described and subsequently compared to conventional methods, and found to give comparable results (Komarek, 1993; Komarek et al., 1994; Vogel et al., 1999). Sodium sulfite and heat-stable α-amylase were not included in the neutral detergent solution. Concentrations of N in these hays were quantified by a rapid combustion procedure (AOAC, 1998, Official Method 990.03; Elementar Americas, Inc. Mt. Laurel, NJ), and crude protein (115 ± 6.5 g kg^{-1}) was calculated by multiplying the percentage of N in the forage by 6.25.

Concomitant with the June weigh day each year, blood samples were collected from each cow via jugular venapuncture, allowed to clot, and then maintained at 4°C for approximately 20 h. Serum was then separated by centrifugation at 1200 *g* for 20 min at 20°C, placed in plastic vials, and then stored at −20°C until concentrations of serum prolactin were determined by radioimmunoassay (Henson et al., 1987).

Statistical Analyses

All response variables were evaluated initially as a repeated measures design with forage systems (OG2W, OG2M, E+2M, E−2W, and E−2M) as whole plots and year as the repeated measures term. Forage systems were tested for significance with the mean square of pasture nested within forage system as the error term. The main effect of year and the forage system × year interaction were tested for significance with the residual error mean square. For most cow and calf performance response variables, calf sex was included initially in the model, and there were few interactions of other treatment effects with calf sex. However, calf sex was not distributed evenly across pastures, and in some cases, one sex or the other was not represented within the five cows assigned to a specific pasture. When this occurred, some means were nonestimable; therefore, the effect of calf sex and all interactions with calf sex were removed from all models. All analyses were conducted with PROC GLM of SAS (SAS Institute, 1989). Four preplanned contrasts were used to evaluate differences among forage systems: (i) E+ vs. OG and E−; (ii) E− vs. OG; (iii) 2W vs. 2M; and iv) the interaction of contrasts comparing nontoxic forages (E− and OG) and rotation frequency (2W and 2M). Data from E+ pastures, which were grazed with the 2M rotation frequency only, were excluded from the 2W vs. 2M contrast. Main effect least square means of year were separated with the PDIFF option of SAS (SAS Institute, 1989). For contrasts evaluating forage systems, statistical trends were identified at $P < 0.10$, and significance was declared at $P < 0.05$. Yearly means were separated at the $P < 0.10$ level of confidence.

RESULTS AND DISCUSSION

Calf Performance

No measure of calf performance was affected ($P \geq 0.253$) by the forage system × year interaction, and only calf birth weight was affected ($P = 0.004$) by the main effect of year. Generally, calf performance was very consistent across years. Annual overall means for total gain, actual weaning weight, age adjusted 205-d weaning weight, and average daily gain ranged tightly from 209 to 214 kg, 245 to 249 kg, 243 to 244 kg, and 1.00 to 1.01 kg d^{-1}, respectively (Table 1). These responses would not be expected if the toxicity of E− and OG pastures increased substantially through reinfection with rogue E+ plants over years; under such conditions, calf performance would be expected to decline, probably resulting in significant effects of year or interactions with year.

Birth weight was not affected ($P > 0.10$) by forage system. Age adjusted 205-d weaning weights for calves raised on E− and OG pastures were greater ($P = 0.034$) over the 4-yr trial by 24 kg than those raised on E+ pastures, and a similar tendency ($P = 0.096$) of 22 kg was observed for actual weaning weight. Previously, Peters et al. (1992) reported respective adjusted 205-d weaning weights of 235, 236, and 212 kg for calves raised on OG, E−, and E+ pastures in central Missouri. Similarly, Watson et al. (2004) reported advantages in 205-d adjusted weaning weights of 28.2 kg for steers and 19.8 kg for heifers raised on tall fescue pastures containing a novel endophyte that produced no ergot alkaloids compared to calves raised on pastures with E+. Although the magnitude of adjusted 205-d weaning weights varied across these studies, the differentials between low- and high-toxicity pastures were remarkably consistent, averaging about 24 kg. Similarly, Paterson et al. (1995) summarized trials comparing cow-calf performance with direct comparisons between E+ and E− forages; the mean advantage for 205-d adjusted weaning weights over four trials for calves raised on E− pastures was 32 kg, which compares closely to the reports described previously. In general, the weight advantage for calves raised on low-toxicity pastures has been relatively consistent across most reported trials. In the present study, dilution of E+ with bermudagrass and other forage grasses (Coblentz et al., 2006) did not appear to affect the magnitude of this weight differential.

Total gain for calves during the interval between birth and weaning tended to be greater ($P = 0.102$) for calves raised on low-toxicity pastures (215 kg) compared to calves raised on E+ (195 kg), and this contrast was significant ($P = 0.035$) when gains were calculated on a daily basis. The mean average daily gain for calves raised on low-toxicity pastures was 1.03 kg d^{-1}, which was an advantage of 0.11 kg d^{-1} over those raised on E+. This differential was smaller than summarized over seven cow-calf performance trials by Paterson et al. (1995) (0.21 kg d^{-1}), or reported by Peters et al. (1992) (0.16–0.17 kg d^{-1}), suggesting the extensive dilution of E+ in the present study may have had a positive effect on the daily performance of calves raised on E+ pastures.

Based on the growth performance of calves in the present study, dilution by nearly 50% with bermudagrass and other forages was not enough to completely offset the toxic effects of E+ plants in these mixed-species pastures. Although a 22-kg differential in actual weaning weights was observed for calves raised on low-toxicity pastures compared to the E+ controls, it should be noted that actual weaning weights for calves raised on E+ pastures averaged 231 kg, which is likely to be viewed as very acceptable performance by cow-calf producers throughout the region. Given the climate, terrain, and soils found commonly throughout the

Table 1. Performance of suckling calves raised on pastures of common bermudagrass mixed with either orchardgrass (OG), endophyte-free tall fescue (E−), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

Treatment	Date of birth†	Birth weight	Total gain‡	Actual weaning weight	Age adjusted 205-d weaning weight	Average daily gain	Age at weaning
	DOY§	kg				kg d^{-1}	d
Forage System							
OG2W	71	38	222	260	253	1.05	212
OG2M	74	37	218	255	253	1.05	207
E+2M	70	36	195	231	225	0.92	212
E−2W	73	37	201	238	234	0.96	210
E−2M	76	37	217	254	252	1.05	206
SEM¶	2.4	0.9	10.8	11.2	9.3	0.043	2.3
Nontoxic (OG and E−)#	73	37	215	253	249	1.03	209
Contrasts				$P > F$			
1) E+ vs. E− + OG	–	NS††	NS	0.096	0.034	0.035	NS
2) E− vs. OG	–	NS	NS	NS	NS	NS	NS
3) 2W vs. 2M	–	NS	NS	NS	NS	NS	NS
4) Interaction‡‡	–	NS	NS	NS	NS	NS	NS
Year							
2000	71	38ab§§	209	246	244	1.01	207
2001	71	35c	214	249	243	1.01	212
2002	76	36bc	209	245	243	1.01	207
2003	73	39a	210	249	243	1.00	211
SEM¶¶	2.0	0.6	3.9	4.1	3.8	0.017	2.0

† Mean date of birth for each forage system and year. No statistical inference is implied about relative differences between pasture systems or across years.
‡ Total gain = weaning weight − birth weight.
§ Day of year.
¶ Pooled standard error of the forage system mean.
# Mean of all OG and E− pastures weighted on the basis of unequal replication.
†† Not significant ($P > 0.10$).
‡‡ Interaction of contrasts 2 and 3.
§§ Yearly means in a column without common letters differ ($P < 0.10$).
¶¶ Standard error of the annual mean.

southern Ozarks (Sauer et al., 1998), a 50% dilution rate for tall fescue is relatively easy to achieve, and often occurs naturally over time; therefore, it is questionable whether producers will be willing to invest in the additional establishment costs and management required to maintain E− or OG forages in this environment. In addition, contrasts of E− vs. OG, 2W vs. 2M, and their associated interaction did not affect ($P \geq 0.164$) any measure of calf performance, suggesting that the choice of nontoxic forage (E− vs. OG) or rotation frequency (2W vs. 2M) had little impact on performance.

Cow Performance

Weights

Most research comparing the productivity of cattle consuming E+ and E− or other low-toxicity pastures has been conducted with stocker cattle; however, Paterson et al. (1995) summarized several studies reporting cow-calf productivity and concluded that cows grazing E+ pastures lost more weight, exhibited reduced milk production, and had lower pregnancy rates than cows raising calves on E− pastures. Generally, our data agree with these assessments. Cow weights at calving, and weight changes between calving and breeding, breeding and weaning, and calving and weaning were not affected ($P \geq 0.179$) by the forage system × year interaction; therefore, only main effects are reported (Table 2) and discussed. Cow weight at calving was greater ($P = 0.011$) for cows grazing low-toxicity pastures (654 kg) than for E+ pastures (609 kg). In addition, there was a tendency ($P = 0.088$) for reduced weight loss between calving and weaning on low-toxicity pastures. Nontoxic forage species, rotation frequency, and their associated interaction had no effect ($P > 0.10$) on cow weights at calving, or weight changes between breeding and weaning, or calving and weaning. However, weight losses between calving and breeding tended to be greater ($P = 0.057$) with the 2W rotation schedule (−37 kg) compared to the less frequent 2M schedule (−20 kg).

The main effect of year affected ($P < 0.0001$) weight at calving, and all response variables describing weight changes between calving, breeding, and weaning. Cow weights at calving increased ($P < 0.10$) during the trial from 571 kg in 2000 to 712 kg in 2003. Weights for 2001 and 2002 were intermediate between these extremes, but differed ($P < 0.10$) from both (Table 2). Weight changes from calving to breeding, and breeding to weaning differed ($P < 0.10$) across years, but these responses were generally erratic, exhibiting no clear pattern. Cows lost more ($P < 0.10$) weight between calving and weaning during 2002 (49 kg) and 2003 (48 kg) than in 2001 (33 kg), while an overall weight gain ($P < 0.10$) of 6 kg was observed for 2000.

Body Condition Scores

The interaction of forage system and year affected BCS at calving ($P = 0.026$) and the change in BCS from calving to breeding ($P = 0.006$); however, BCS at calving increased over years within each forage system, suggesting that the interaction was created by differences in magnitude. Changes in BCS from calving to breeding generally declined over years within all forage systems, but

Table 2. Body weights and weight changes of cows grazing pastures of common bermudagrass mixed with either orchardgrass (OG), endophyte-free tall fescue (E−), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

Treatment	Initial weight†	Weight at calving‡	Weight change calving to breeding	Weight change breeding to weaning	Weight change calving to weaning
	kg				
Forage System					
OG2W	536	632	−35	10	−27
OG2M	526	670	−20	10	−11
E+2M	563	609	−34	−7	−45
E−2W	552	660	−40	−2	−45
E−2M	546	665	−19	−7	−28
SEM§	18.9	11.1	4.2	3.9	5.3
Nontoxic (OG and E−)¶	540	654	−29	4	−28
Forage System Contrasts			*P* > *F*		
1) E+ vs. E− + OG	–	0.011	NS#	NS	0.088
2) E− vs. OG	–	NS	NS	NS	NS
3) 2W vs. 2M	–	NS	0.057	NS	NS
4) Interaction††	–	NS	NS	NS	NS
Year					
2000	547	571c‡‡	5a	1b	6a
2001	–	643b	−45c	13a	−33b
2002	–	662b	−15b	−32c	−49c
2003	–	712a	−64d	21a	−48c
SEM§§	69.3¶¶	10.3	3.9	3.6	4.9

† Weight of cows allocated to pastures on 11 Jan. 2000.
‡ Weight of cows on the last monthly weigh day before the onset of calving; mean of 4 yr.
§ Pooled standard error of forage system mean.
¶ Mean of all OG and E− pastures weighted on the basis of unequal replication.
# Not significant ($P > 0.10$).
†† Interaction of contrasts 2 and 3.
‡‡ Yearly means in a column without common letters differ ($P < 0.10$).
§§ Standard error of the annual mean.
¶¶ Standard deviation of mean weight of cows allocated to pastures on 11 Jan. 2000.

responses also were erratic, thereby resulting in an interaction of main effects. Changes in BCS from breeding to weaning and from calving to weaning did not exhibit an interaction ($P \geq 0.325$). For these reasons, interactions will be ignored, and only main effects will be reported and discussed. At calving, BCS were greater ($P = 0.021$; Table 3) by 0.3 units for cows grazing low-toxicity pastures than for cows grazing E+ pastures; however, BCS at calving were ≥6.7 for all forage systems, which should be more than adequate to optimize pregnancy rates (Selk et al., 1988). Losses in BCS from breeding to weaning, and from calving to weaning were greater ($P = 0.014$) or tended to be greater ($P = 0.076$), respectively, for cows grazing E+ pastures compared to low-toxicity pastures. The differential over both production intervals was 0.3 BCS units. Forage system had no effect ($P > 0.10$) on changes in BCS from calving to breeding, but there was a tendency ($P = 0.098$) for cows to gain more condition between calving and breeding when they grazed low-toxicity pastures rotated 2M compared to 2W.

The main effect of year affected ($P < 0.0001$) BCS at calving and changes in BCS over each production interval. Between 2000 and 2003, BCS at calving increased each year ($P < 0.10$), ranging from 6.2 to 7.6 (Table 3). For each production interval, changes in BCS were positive in 2000 and became negative ($P < 0.10$) by 2003, but the magnitude and extent of change in each specific year varied with the production interval.

Milk Production

For both May and July milk production, there was no interaction ($P \geq 0.102$) of forage system with year; therefore, only main effect means are summarized (Table 4) and discussed. Milk production in May was greater ($P = 0.036$) by 1.1 kg for cows grazing low-toxicity pastures compared to E+, but this difference was not observed during July ($P > 0.10$). During May, the difference between milk production on low-toxicity and E+ pastures represented a 17% reduction for cows grazing E+ pastures, which agrees closely with the 25% reduction reported by Peters et al. (1992), and may partially explain the increased weaning weights for calves raised on low-toxicity pastures (Table 1). Similarly, Brown et al. (1993) reported an 18% reduction in milk production over 3 yr for Angus and Brahman cows grazing E+ compared to nontoxic common bermudagrass.

During May and July, there was an interaction ($P = 0.035$) or tendency for an interaction ($P = 0.066$), respectively, of contrasts comparing E− with OG and 2W with 2M. These interactions can be explained on the basis of numerically greater milk production with 2W compared to 2M for cows grazing OG pastures; however, the inverse relationship occurred for E− pastures. The main effect of year affected milk production for both May ($P < 0.0001$) and July ($P = 0.003$) evaluations. Although milk production varied ($P < 0.10$) across years for both May and July, there was no clear pattern across years except that the numerically minimum production was observed for both evaluation times during 2001.

Serum Prolactin

As observed for most other response variables, there was no interaction ($P = 0.128$) of forage system with year for serum prolactin. Concentrations of serum prolactin

Table 3. Body condition scores (BCS; scale of 1–9; 1 = emaciated, 9 = obese) of cows grazing pastures of common bermudagrass mixed with either orchardgrass (OG), endophyte-free tall fescue (E−), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

Treatment	Initial BCS†	BCS at calving‡	BCS change calving to breeding	BCS change breeding to weaning	BCS change calving to weaning
Forage System					
OG2W	6.1	6.8	0.2	0.1	0.3
OG2M	6.3	7.0	0.3	0.0	0.3
E+2M	6.3	6.7	0.2	−0.3	−0.1
E−2W	6.2	7.1	0.1	0.0	0.0
E−2M	6.2	7.2	0.3	−0.2	0.1
SEM§	0.16	0.07	0.09	0.08	0.10
Nontoxic (OG and E−)¶	6.2	7.0	0.2	0.0	0.2
Forage system contrasts			$P > F$		
1) E+ vs. E− + OG	–	0.021	NS#	0.014	0.076
2) E− vs. OG	–	NS	NS	NS	NS
3) 2W vs. 2M	–	NS	0.098	NS	NS
4) Interaction††	–	NS	NS	NS	NS
Year					
2000	6.2	6.2d‡‡	0.4a	0.5a	1.0a
2001	–	6.8c	0.5a	−0.2b	0.2b
2002	–	7.3b	0.1b	−0.3b	−0.3c
2003	–	7.6a	−0.2b	−0.3b	−0.4c
SEM§§	0.59¶¶	0.07	0.08	0.08	0.09

† Body condition score of cows allocated to pastures on 11 Jan. 2000.
‡ Body condition score of cows on the last monthly assessment before calving; mean of 4 yr.
§ Pooled standard error of forage system mean.
¶ Mean of all OG and E− pastures weighted on the basis of unequal replication.
# Not significant ($P > 0.10$).
†† Interaction of contrasts 2 and 3.
‡‡ Yearly means in a column without common letters differ ($P < 0.10$).
§§ Standard error of the annual mean.
¶¶ Standard deviation of mean BCS of cows allocated to pastures on 11 Jan. 2000.

Table 4. Milk production, concentrations of serum prolactin, pregnancy rates, and cow age for cows grazing pastures of common bermudagrass mixed with either orchardgrass (OG), endophyte-free tall fescue (E−), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

Treatment	Initial age†	May milk production	July milk production	Serum prolactin	Pregnancy rate	Cow age‡
	yr	kg d^{-1}		ng mL^{-1}	%	yr
Forage system						
OG2W	4.4	7.2	4.4	168	81.7	4.8
OG2M	4.0	6.2	4.0	151	92.5	4.7
E+2M	5.0	5.4	4.0	84	82.5	4.8
E−2W	4.5	5.5	3.4	121	87.5	5.1
E−2M	4.2	6.9	4.8	179	90.0	5.1
SEM§	0.52	0.42	0.38	25.2	7.72	0.34
Nontoxic (OG and E−)¶	4.3	6.5	4.2	156	87.2	4.9
Forage System Contrasts			$P > F$			
1) E+ vs. E− + OG	–	0.036	NS#	0.022	NS	NS
2) E− vs. OG	–	NS	NS	NS	NS	NS
3) 2W vs. 2M	–	NS	NS	NS	NS	NS
4) Interaction††	–	0.035	0.066	NS	NS	NS
Year						
2000	4.5	6.0b‡‡	4.0b	145b	78.0b	4.4b
2001	–	4.7c	3.2b	137b	93.3a	4.7ab
2002	–	6.5b	5.3a	182a	86.7ab	5.2a
2003	–	7.7a	3.9b	98c	89.3a	5.2a
SEM§§	1.90¶¶	0.36	0.41	15.4	4.14	0.28

† Age of cows allocated to pastures on 11 Jan. 2000.
‡ Age of cows at calving; mean of 4 yr.
§ Pooled standard error of forage system mean.
¶ Mean of all OG and E− pastures weighted on the basis of unequal replication.
# Not significant ($P > 0.10$).
†† Interaction of contrasts 2 and 3.
‡‡ Yearly means within a column without common letters differ ($P < 0.10$).
§§ Standard error of the annual mean.
¶¶ Standard deviation of the mean age of cows allocated to pastures on 11 Jan. 2000.

(Table 4) for cows grazing low-toxicity pastures were approximately twice as great (156 ng mL^{-1}; $P = 0.022$) as those observed for cows grazing E+ pastures (84 ng mL^{-1}). No other contrasts of forage system affected concentrations of serum prolactin ($P > 0.10$). Serum prolactin also varied ($P = 0.002$) with year; concentrations were greatest ($P < 0.10$) in 2002, and lowest ($P < 0.10$) in 2003. For 2000 and 2001, serum prolactin was intermediate ($P < 0.10$) between concentrations observed during 2002 and 2003, but they did not differ ($P > 0.10$) from each other.

Numerous studies have shown that concentrations of serum prolactin decrease consistently in livestock consuming E+, presumably in response to consumption of toxic ergot alkaloids; this is viewed frequently as a measurable result of fescue toxicosis (Paterson et al., 1995). While many studies have reported this response for stocker cattle (Nihsen et al., 2004; Parish et al., 2003; Fribourg et al., 1991), limited data are available describing concentrations of serum prolactin in cows consuming E+ compared to low-toxicity pastures.

Pregnancy Rates

Summaries of previous studies compiled by Paterson et al. (1995) suggest that greater pregnancy rates should be expected for cows grazing low-toxicity pastures compared to those grazing E+. Differences reported within these studies ranged from 15 to 40% units; however, another similar study by Watson et al. (2004) reported no difference in calving rate for cows grazing low or high ergot alkaloid–producing pastures. Pregnancy rates were not the primary focus of this systems study, and inadequate numbers may have prevented detection of differences in pregnancy rates. Overall, pregnancy rates were not affected by forage system ($P \geq 0.456$), and cows grazing low-toxicity pastures exhibited rates (87.2%) that were only numerically greater ($P > 0.10$) than observed for E+ (82.5%). However, the mean rate over all forage systems and years was 85.8%, which exceeds a 4-yr average of 73.5% for Angus and Brahman cows grazing E+ pastures in western Arkansas (Brown et al., 1992), and a 3-yr average of 75.3% for Angus, Brahman, and reciprocal cross cows grazing E+ pastures in the same environment (Brown et al., 2000). Pregnancy rates tended ($P = 0.087$) to vary with year. The poorest pregnancy rate (78.0%; Table 4) was observed during the initial year of the trial, but it increased ($P < 0.10$) to 93.3% in 2001, and remained relatively static ($P > 0.10$) thereafter.

Cow Age

In this study, any cow declared open via rectal palpation or without a live calf at the end of the calving season was replaced by a primiparous cow and her calf. Based on previous research summarized by Paterson et al. (1995), reduced pregnancy rates are observed commonly in cow herds grazing E+ pastures; therefore, it might be hypothesized that the mean age of cows grazing E+ pastures would differ over time when compared to those cows grazing E− or OG pastures. A greater incidence of primiparous replacements in E+ pastures each year would not only result in a reduced mean age relative to the other nontoxic forage systems, but also would potentially impact milk production, weaning weights, and pregnancy rates during the next and following years. However, this did not occur. Forage system

($P \geq 0.370$) and the forage system × year interaction ($P = 0.932$) had no effect on cow age during the 4-yr trial. There was a tendency ($P = 0.092$) for a main effect of year on cow age; cows averaged 4.4 yr in 2000 and increased ($P < 0.10$) to 5.2 yr in both 2002 and 2003 (Table 4). Cow age in 2001 was numerically intermediate, but did not differ ($P > 0.10$) from either extreme.

Performance of Extra Grazing Cows

For extra grazing cows, total grazing days per hectare varied only with year ($P < 0.0001$). Total grazing days per hectare for extra cows (Table 5) were greatest ($P < 0.10$) in 2003 (93 d ha^{-1}), when monthly rainfall in May and June exceeded the 30-yr norm by 148 and 56 mm, respectively (NOAA, 2002). In contrast, the fewest extra grazing days (29 d ha^{-1}) occurred during 2001, when rainfall totals for March, April, May, and June were all below the 30-yr norm, thereby creating a rainfall deficit of 205 mm during this time period. Other years were intermediate ($P < 0.10$) between 2001 and 2003.

Total weight gain for extra grazing cows (Table 5) was greater ($P = 0.001$) for cows grazing low-toxicity pastures (73 kg cow^{-1}) compared to E+ pastures (45 kg cow^{-1}). Unlike all other response variables evaluated for cows and calves, total weight gain for extra cows grazing OG pastures differed ($P = 0.016$) from those grazing E− pastures. For OG, total gain per cow was 82 kg, which exceeded that for E− (63 kg) by 19 kg. Yearly effects on total gains were related closely to total grazing days; the greatest total gains ($P < 0.10$) were observed in 2003 (110 kg cow^{-1}), when above-normal spring rainfall supported prolonged extra grazing. The poorest gains ($P < 0.10$) occurred during 2001 (32 kg cow^{-1}), when a deficit of spring rainfall limited extra grazing days.

For both average daily gain and changes in body condition score, there were tendencies ($P \leq 0.080$) for interactions of forage system and year; however, these were likely caused by very erratic responses within E− pastures during 2000 and 2001 (data not shown), rather than clear patterns of interactive effects. For this reason, only main-effect means are reported and discussed (Table 5). Average daily gain was greater ($P = 0.003$) for extra grazing cows on low-toxicity pastures compared to those on E+ controls. This difference was about 0.55 kg d^{-1}, which was an 86% increase relative to daily gains by extra cows assigned to E+ pastures. Within low-toxicity pastures, daily gains for cows assigned to OG pastures (1.35 kg d^{-1}) exceeded ($P = 0.043$) those assigned to E− pastures (1.00 kg d^{-1}). Changes in the BCS for extra grazing cows followed patterns across forage systems that were similar to those observed for average daily gain; BCS increased by 1.1 units for cows grazing low-toxicity pastures compared to only 0.8 units for E+ ($P = 0.049$). Increases in BCS for OG pastures (1.3 units) also exceeded ($P = 0.044$) those for E− (1.0 units).

Reasons for the difference in performance between extra cows grazing OG and E− pastures remain unclear, but it is unlikely that forage mass or the nutritive value of the forages were factors. Concentrations of crude protein and in vitro DM disappearance (IVDMD) were not affected by forage system or interactions of forage system

Table 5. Growth performance of extra "thin" fall-calving grazing cows used to harvest the flush of spring forage growth in mixed-species pastures that contained common bermudagrass with either endophyte-free tall fescue (E−), orchardgrass (OG), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

Treatment	Total cow grazing days per hectare	Initial bodyweight	Total weight gain	Average daily gain	Change in body condition score†	Total gain per hectare
	d ha^{-1}	kg cow^{-1}		kg d^{-1}		kg ha^{-1}
Forage System						
OG2W	68	472	85	1.39	1.3	87
OG2M	63	468	78	1.30	1.3	80
E+2M	61	478	45	0.64	0.8	47
E−2W	61	489	62	0.97	1.1	64
E−2M	56	478	63	1.02	0.8	64
SEM‡	4.0	13.9	4.2	0.121	0.14	5.8
Nontoxic (OG and E−)§	63	476	73	1.19	1.1	75
Forage System Contrasts			$P > F$			
1) E+ vs. E− + OG	NS¶	–	0.001	0.003	0.049	0.001
2) E− vs. OG	NS	–	0.016	0.043	0.044	0.009
3) 2W vs. 2M	NS	–	NS	NS	NS	NS
4) Interaction#	NS	–	NS	NS	NS	NS
Year						
2000	67b††	495‡‡	82b	1.43a	1.4a	95a
2001	29c	507	32d	0.99b	1.1a	36b
2002	59b	504	44c	0.71c	1.2a	41b
2003	93a	401	110a	1.13b	0.6b	103a
SEM§§	3.8	13.1	4.0	0.114	0.13	5.4

† Body condition scores were evaluated when extra cows were assigned to and removed from pastures based on a scale of 1 to 9, where 1 = emaciated and 9 = obese (Davis, 1995).
‡ Pooled standard error of the forage system mean.
§ Mean of all OG and E− pastures weighted on the basis of unequal replication.
¶ Not significant ($P > 0.10$).
# Interaction of contrasts 2 and 3.
†† Yearly means within a column without common letters differ ($P < 0.10$).
‡‡ Weights represent the mean initial body weight for each year. No statistical inference is implied about relative differences between initial weights across years.
§§ Standard error of the mean.

with year (Coblentz et al., 2006). Furthermore, forage mass was not affected by forage system during either 2000 or 2001; although there were forage system × sampling date interactions for both 2002 and 2003, forage mass for OG was generally less than observed for to E− pastures during the late spring (Coblentz et al., 2006). It should be noted that our monthly pasture evaluation techniques were based on uniform representation of the entire 4-ha pasture; while this was necessary to accommodate personnel and logistical issues, it also may have masked subtle differences between individual paddocks of E− and OG at the time they were being grazed.

Both average daily gain ($P = 0.002$) and changes in BCS ($P = 0.003$) for extra grazing cows were affected by year. Average daily gain varied ($P < 0.10$) from a numerical low of 0.71 kg d^{-1} during 2002 to a maximum of 1.43 kg d^{-1} during 2000, while other years were intermediate ($P < 0.10$) between these extremes. Changes in BCS did not differ ($P > 0.10$) from 2000 through 2002, averaging 1.2 units over the initial 3 yr of the trial. These increases were greater ($P < 0.10$) than observed during 2003, when increases in BCS declined by about 50% to 0.6 units.

Total gain per hectare by extra grazing cows (Table 5) was greater ($P = 0.001$) for cows grazing low-toxicity pastures (75 kg ha^{-1}) compared to E+ pastures (47 kg ha^{-1}), which represents a 60% improvement relative to E+ controls. As observed for total weight gain (kg cow^{-1}), average daily gain, and changes in BCS, there was an advantage (20 kg ha^{-1}; $P = 0.009$) for OG pastures compared to E−. Gain per hectare varied ($P < 0.0001$) with year and was greatest ($P < 0.10$) during 2000 and 2003, averaging 99 kg ha^{-1} over these 2 yr. In contrast, gains per hectare were poorer ($P < 0.10$) in 2001 and 2002, averaging only 39 kg ha^{-1}. Generally, gain per hectare was related closely to total grazing days per hectare; only 29 grazing d ha^{-1} were recorded for 2001 when extra cows gained only 36 kg ha^{-1}, while extra cows gained 103 kg ha^{-1} during 2003 when a maximum of 93 grazing d ha^{-1} were measured.

Hay Offered

All bermudagrass hay was offered during the winter months, except during 2000 when 43, 46, 49, 53, and 51% of the annual total was offered during the summer on OG2W, OG2M, E+2M, E−2W, and E−2M pastures, respectively. The amount of hay offered to supplement available forage was affected by the interaction of forage system and year ($P = 0.026$). Because of the strong interaction of main effects, contrasts were reevaluated by year. During 2000 and 2001, less ($P \leq 0.028$) hay was offered on E+ pastures than on low-toxicity pastures, but this difference was not observed during 2002 or 2003 (Table 6). An important consideration for comparing pasture systems within the southern Ozarks is the expected requirement for supplementation with hay; therefore, the 4-yr average for each forage system is particularly relevant. Overall, hay offered on all low-toxicity forage systems (overall mean = 1805 kg cow^{-1} yr^{-1}) was greater ($P = 0.0002$) by 389 kg cow^{-1} yr^{-1} than observed for E+ pastures. Intuitively, this could be explained on the basis of reduced forage intakes by cows grazing E+ pastures relative to intakes on E− or OG pastures; however, these responses have been observed most frequently when environmental temperatures are high, and not when temperatures are cooler (Peters et al., 1992).

Table 6. Hay offered on mixed-species pastures that contained common bermudagrass with either endophyte-free tall fescue (E−), orchardgrass (OG), or endophyte-infected tall fescue (E+), and grazed with twice weekly (2W) or twice monthly (2M) rotation schedules near Batesville, AR (2000 through 2003).

	Year				
Forage system	2000	2001	2002	2003	2000–2003†
			kg cow^{-1}		
OG2W	2168	2038	1493	1755	1863
OG2M	2116	1858	1652	1755	1845
E+2M	1445	1084	1562	1574	1416
E−2W	1755	1766	1497	1548	1642
E−2M	2116	1923	1665	1652	1839
SEM‡	225.0	62.1	62.6	102.0	67.3
Nontoxic (OG and E−)§	2053	1912	1567	1686	1805
Forage System Contrasts			$P > F$		
1) E+ vs. E− + OG	0.028	<0.0001	NS¶	NS	0.0002
2) E− vs. OG	NS	NS	NS	NS	NS
3) 2W vs. 2M	NS	NS	0.046	NS	NS
4) Interaction#	NS	0.040	NS	NS	NS

† Mean of 4 yr (2000 through 2003).
‡ Pooled standard error of the forage system mean.
§ Mean of all OG and E− pastures weighted on the basis of unequal replication.
¶ Not significant ($P > 0.10$).
# Interaction of contrasts 2 and 3.

Previously, Hoveland et al. (1997) reported a 340 kg cow^{-1} yr^{-1} reduction in hay offered when rotational stocking techniques were used to manage mixed-species pastures of E− and common bermudagrass compared to pastures grazed with continuous stocking. In the present study, cows assigned to OG and E− pastures and grazed with the more frequent 2W rotation schedule were offered less hay ($P = 0.046$) than those assigned to the 2M rotation schedule during 2002, but this did not occur ($P > 0.10$) during any other year. Averaged over all years, there was no difference ($P > 0.10$) between the amounts of hay offered on 2W pastures compared to 2M.

IMPLICATIONS

Over 4 yr, actual and age-adjusted 205-d weaning weights for calves raised on mixed-species pastures consisting of OG or E− mixed with bermudagrass exceeded by 22 and 24 kg, respectively, weights observed for calves raised on E+ pastures diluted by approximately 50% with bermudagrass and a variety of other forages. While it is apparent that this relatively high level of dilution within E+ pastures was not sufficient to completely negate the effects of toxins produced by the endophytic association of *N. coenophialum* with tall fescue, the mean actual weaning weight for calves raised on E+ pastures was 231 kg, which is quite likely to be acceptable performance for small, part-time cow-calf producers in the southern Ozarks. Generally, cow performance differed only marginally for cows grazing E+ compared to E− or OG pastures. Overall, the magnitude of differences between cow and calf performance on OG or E− pastures compared to E+ was relatively small, and this may limit producer adaptation of OG and E− forages, especially when the additional management required for persistence in the southern Ozarks is considered.

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